Monitoring the International Land Borders of the United States Using High Resolution Imagery

Lloyd L. Coulter & Douglas A. Stow
Dept. of Geography
San Diego State University

SAN DIEGO STATE UNIVERSITY

Smuggling of People and Contraband Into the United States

1) Ports of Entry
2) Air
3) Over land
4) Under Ground

Smuggling of People and Contraband Into the United States

1) Ports of Entry
2) Air
3) Over Land
   - trails
   - roads
   - disturbance
4) Under Ground

Smuggling of People and Contraband Into the United States

1) Ports of Entry
2) Air
3) Over Land
4) Under Ground
   - spoil piles
   - land cover disturbance
   - new construction


Cross-border drug tunnel discovered by U.S. Customs agents in May 1990

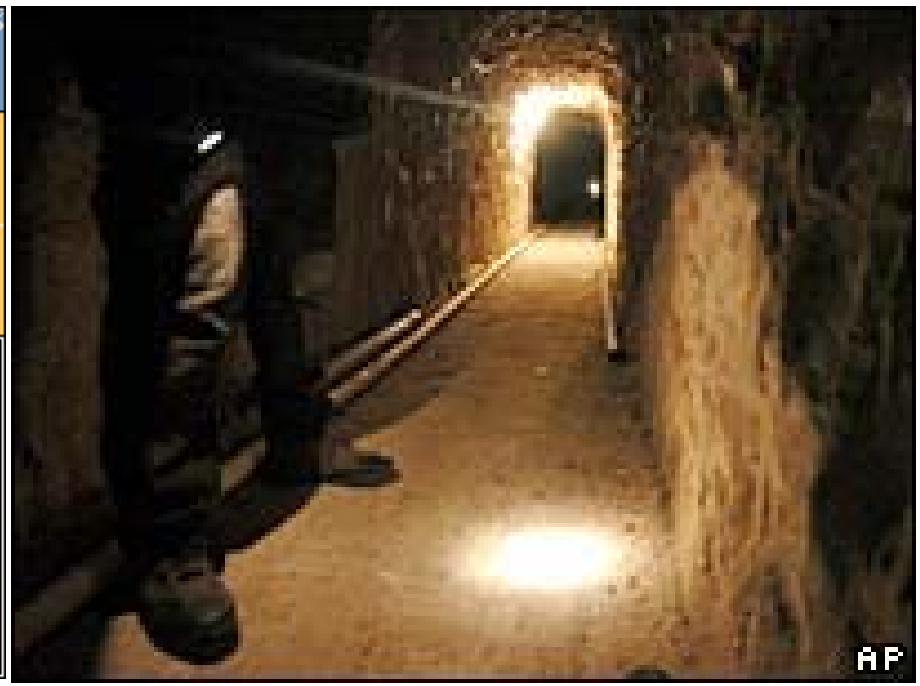


Image-based Monitoring of the U.S. Land Borders

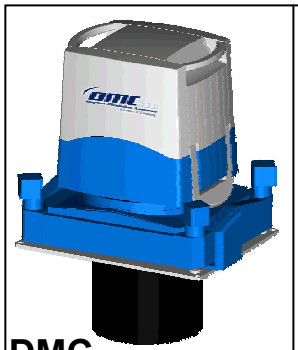
- May be performed using a variety of imagery to:
  - Monitor land cover changes
  - Detect active smuggling routes & infrastructure
  - Improve Border Patrol posture and interdiction success

Commercial Airborne Multispectral Digital Image (0.2 to 1 m)

USGS Color Infrared Digital Ortho-photograph (1 m)

Commercial Satellite Image (0.5 to 4 m)

Large Format Digital Imaging Systems & U.S. Land Border Imagery Collection



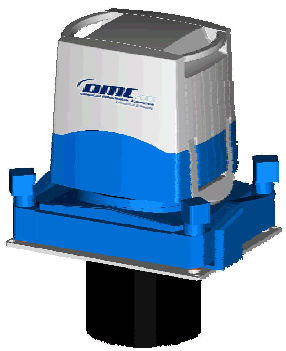
NGA, USGS, USBP 2008/2009 Imagery

- Nationwide land borders
  - 30 miles into US
  - 10 miles into Mexico/Canada
- 1 ft spatial resolution
  - 6” for ports of entry
- 3-band true color (RGB)
- Separate near-infrared (NIR) band
- Currently collecting/processing
- 3001, Inc. leading effort, many subs
  - DMC and ADS40 systems

Imagery will be publicly available and provides an excellent baseline for detecting future changes

NGA - U.S. Land Border Imagery Collection

ADS40



DMC

3001
a Northrop Grumman company

Large Format Imagery
- large area coverage
- high resolution
(10-100 cm)

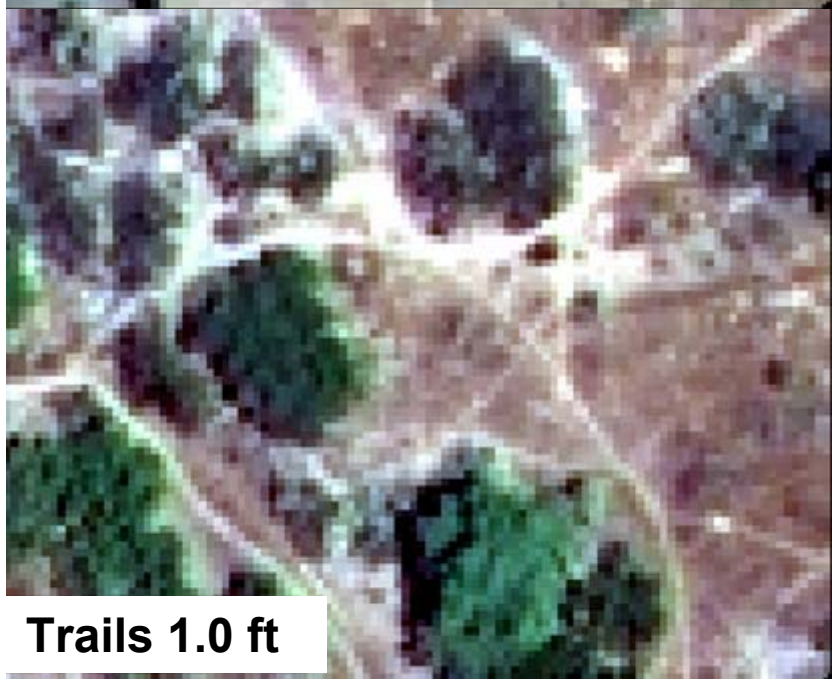
Spatial Coverage
100 - 10000 km^2

U.S. Border Imagery Collection – DMC Simulated Imagery

Urban 0.5 ft

Urban 1.0 ft

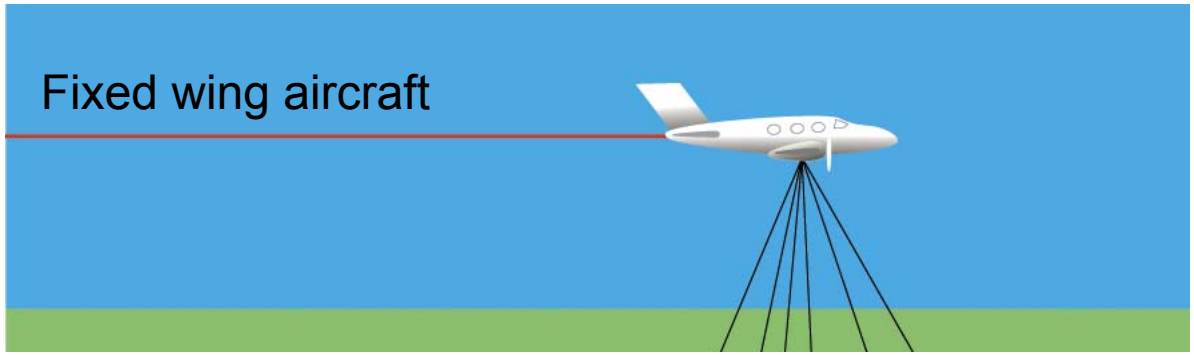
Trails 0.5 ft



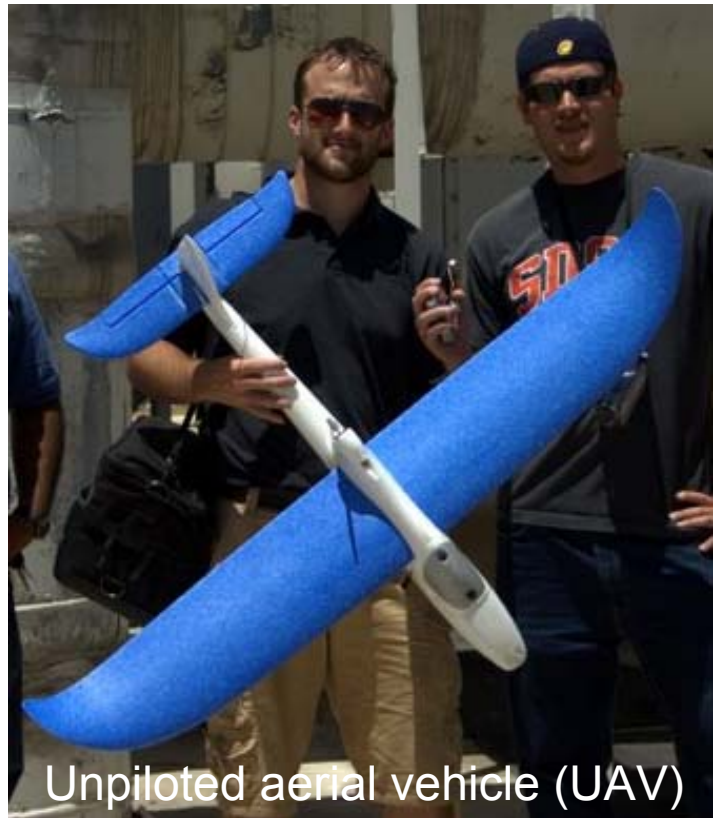
Trails 1.0 ft

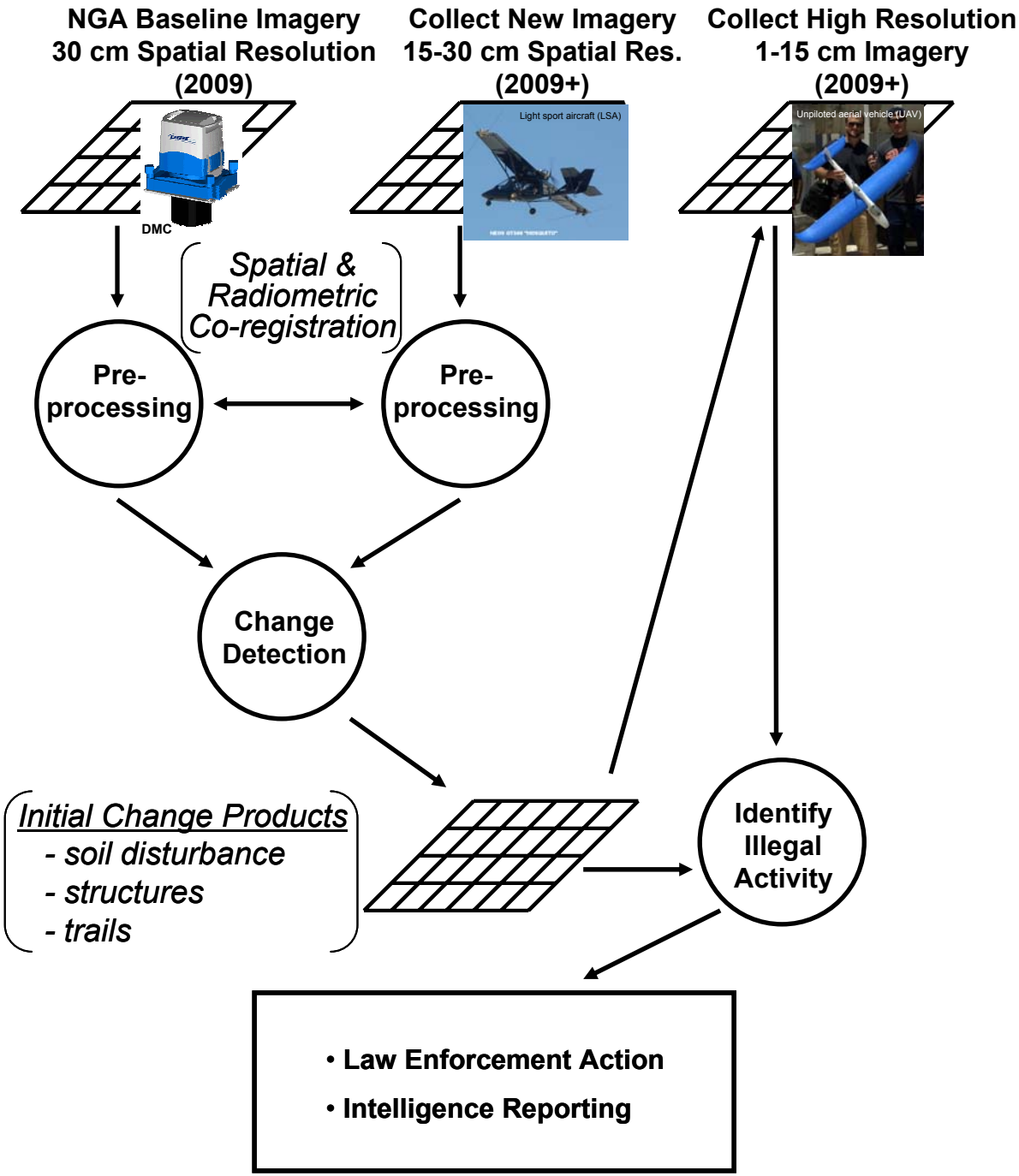
Repeat Imaging & Change Detection

Traditional Large Format Systems



Low-cost Platform/Sensor Combinations

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Light Sport Aircraft (LSA) – Medium Format Imagery

Spatial Resolution
~ 5–60 cm

Spatial Coverage
10 - 1000 km^2

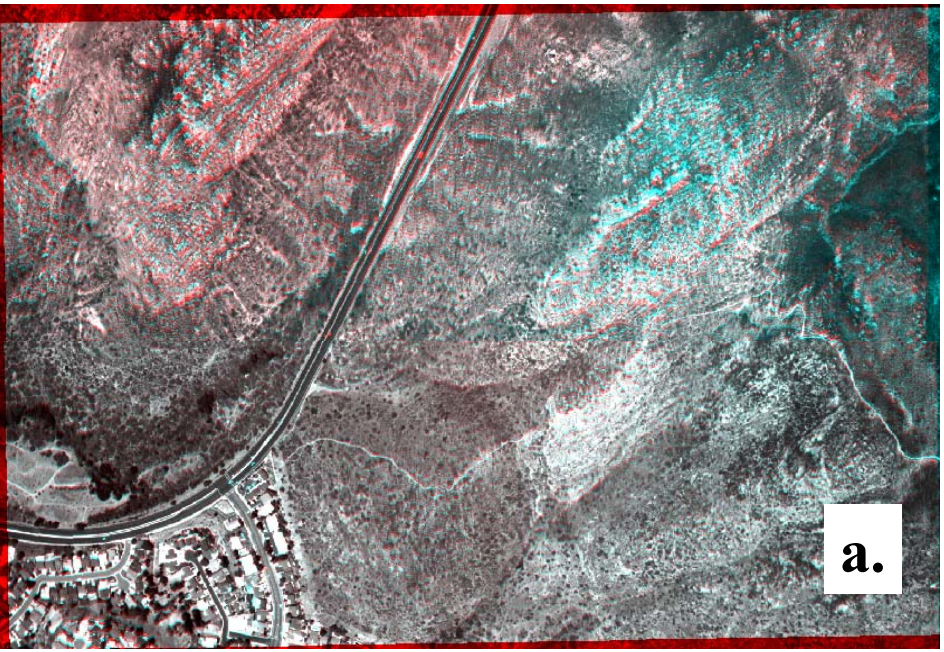
Unpiloted Aerial Vehicle (UAV) – Small Format Imagery

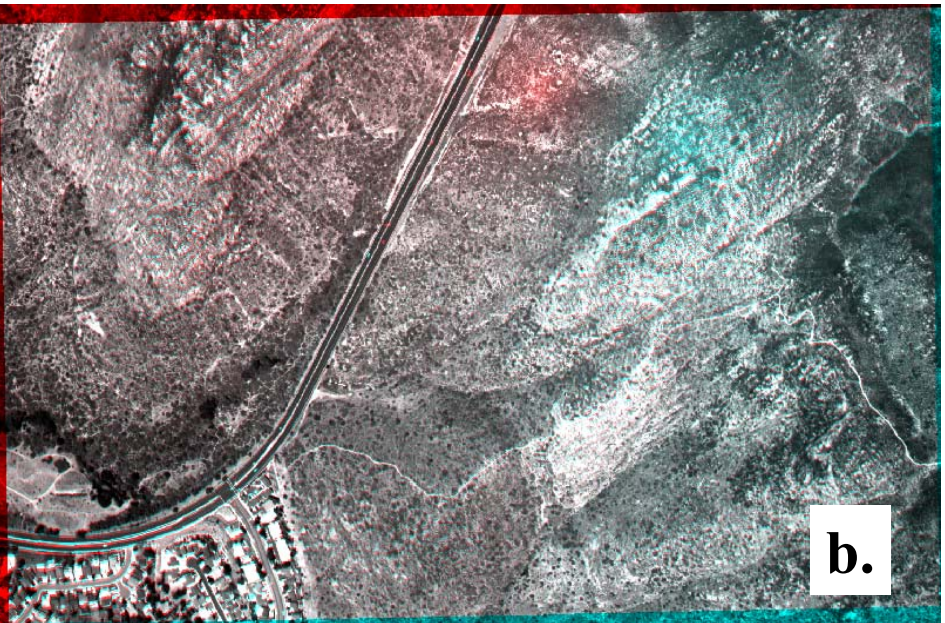
Spatial Resolution
~1–5 cm

Spatial Coverage
0.1 - 10 km^2

Image Preprocessing for Detailed Change Detection

Spatial Co-registration of Multitemporal Imagery



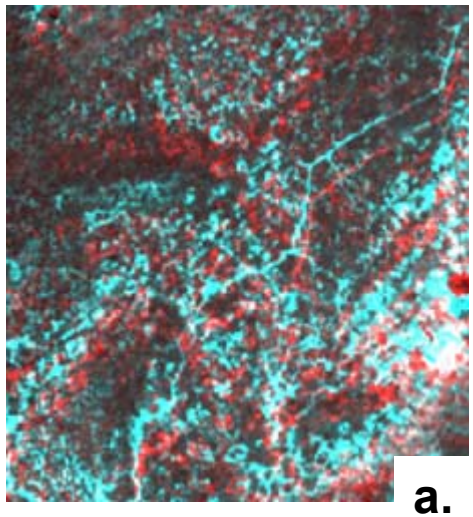


Accurate Spatial Co-registration Requires

- accurate absolute positioning
  (*Coulter and Stow, 2008*)
  - GPS/IMU
  - survey control
  - terrain (LIDAR), stereo imagery, etc.

or

- accurate relative positioning
  - Frame Center Matching approach
    (*Coulter et al., 2003*)



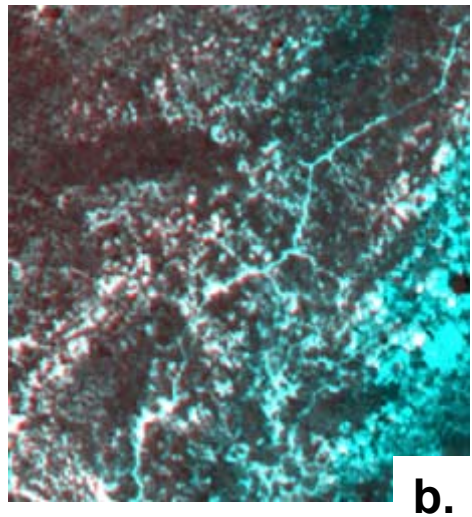


Image Preprocessing for Detailed Change Detection

Multitemporal Co-registration of ADS40, DMC, and UltraCam Imagery

Coulter, L. and D. Stow. 2008. Assessment of the Spatial Co-registration of Multitemporal Imagery from Large Format Digital Cameras in the Context of Detailed Change Detection. Sensors 2008, 8, 2161-2171

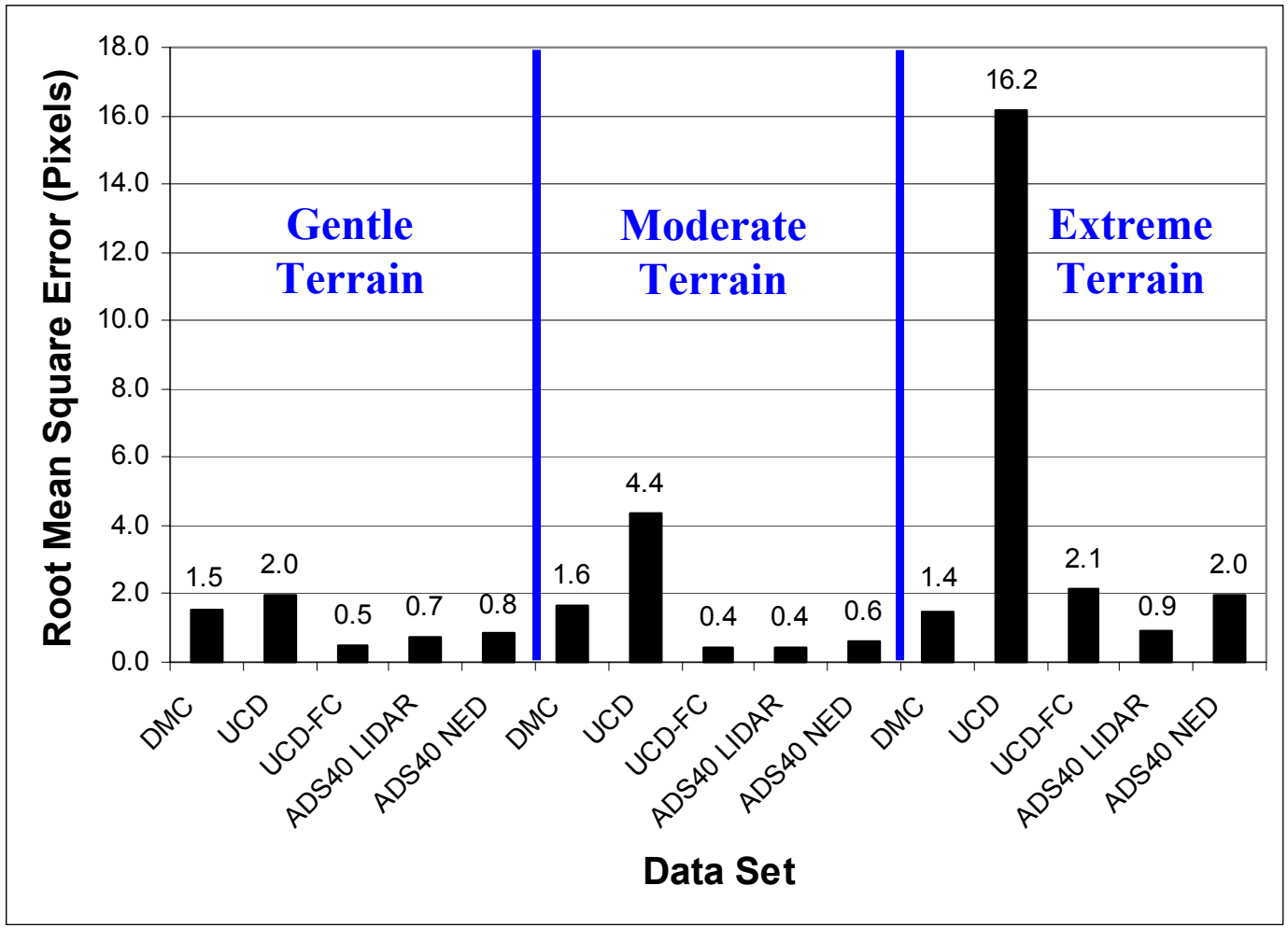
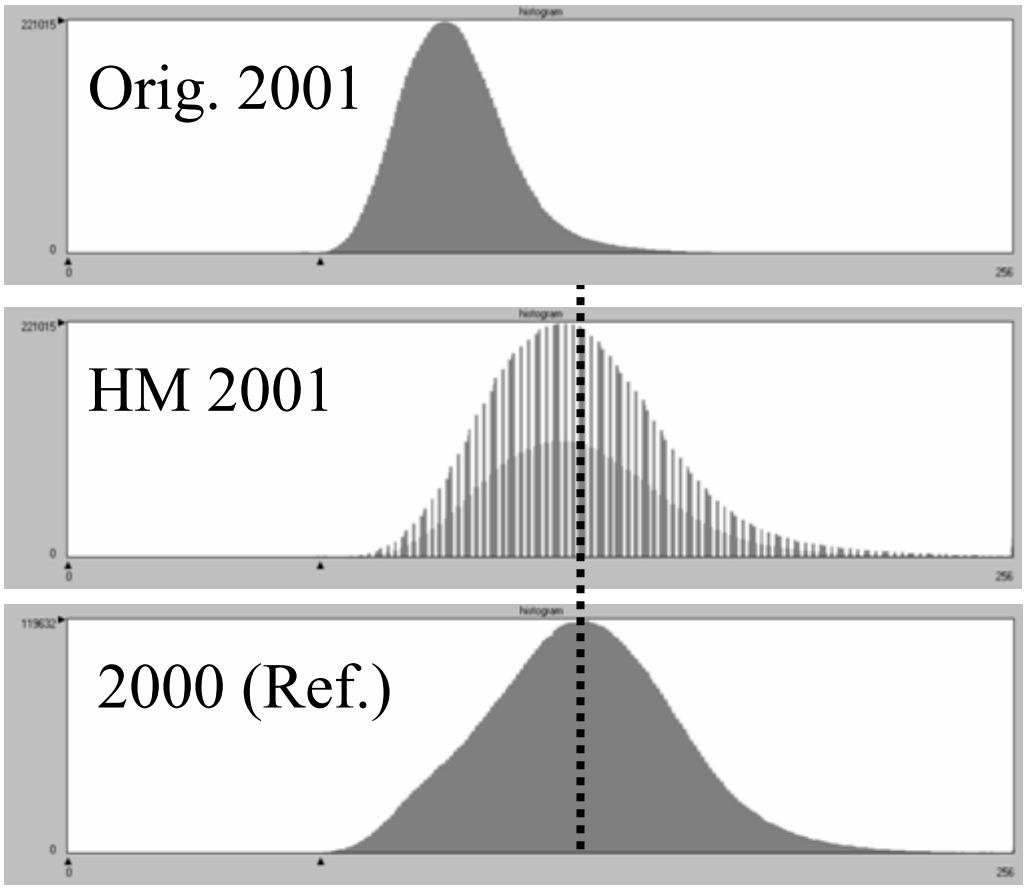


Image Preprocessing for Detailed Change Detection

Radiometric Normalization: Histogram Matching

Yuan, D., & Elvidge, C. (1996). Comparison of relative radiometric normalization techniques. ISPRS Journal of Photogrammetry and Remote Sensing, 51, 117–126.



Mean-Standard Deviation Normalization

Image Preprocessing for Detailed Change Detection

Radiometric Normalization: Histogram Matching

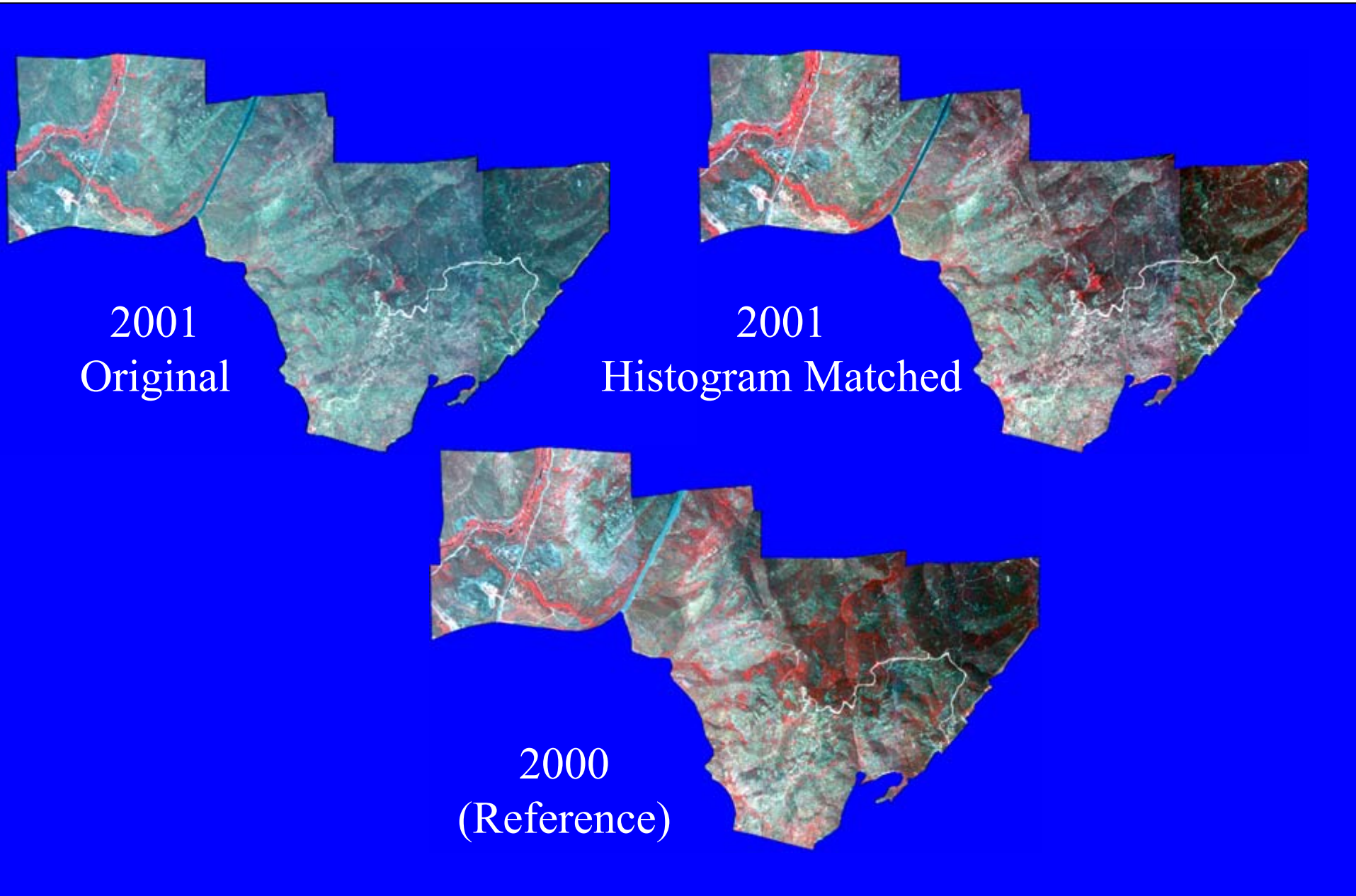
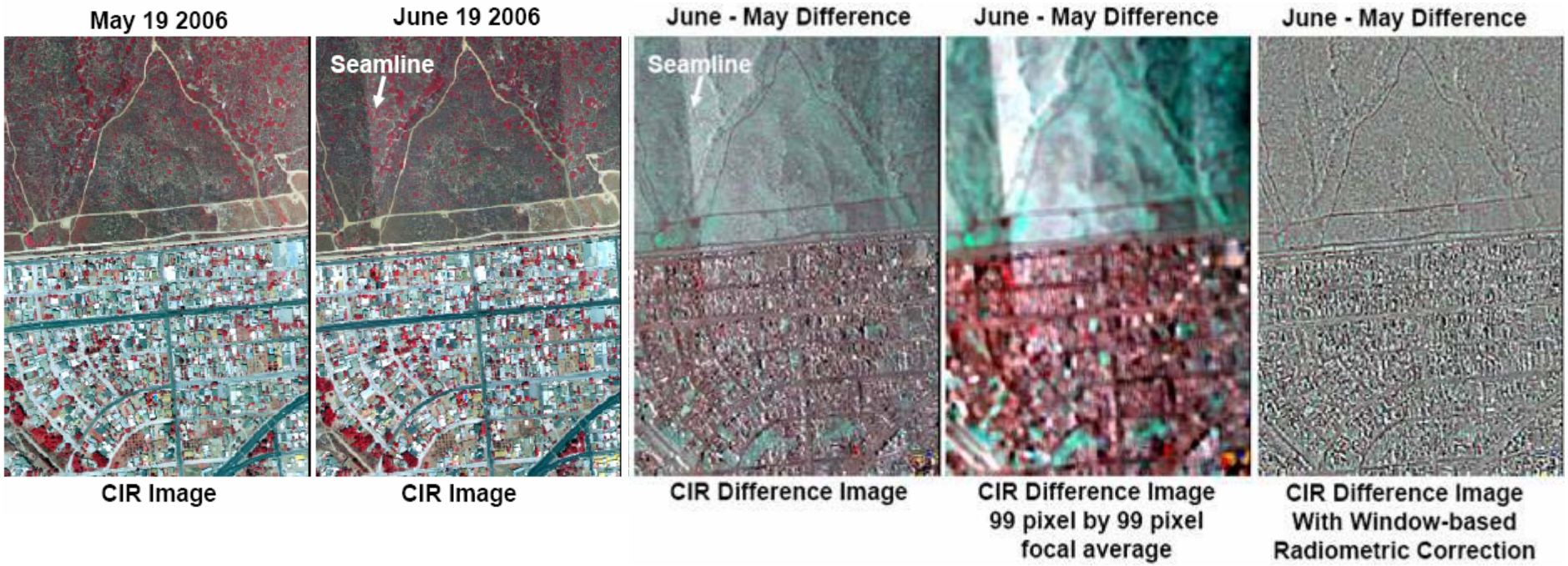


Image Preprocessing for Detailed Change Detection

Radiometric Normalization: Window-based

Window-based radiometric normalization:

1. create difference image,
2. apply low pass filter to difference image
   - smooths to identify local trends
   - 99x99 window, every 11th row/column
3. subtract local trends from the original difference image (or Time-2 image).



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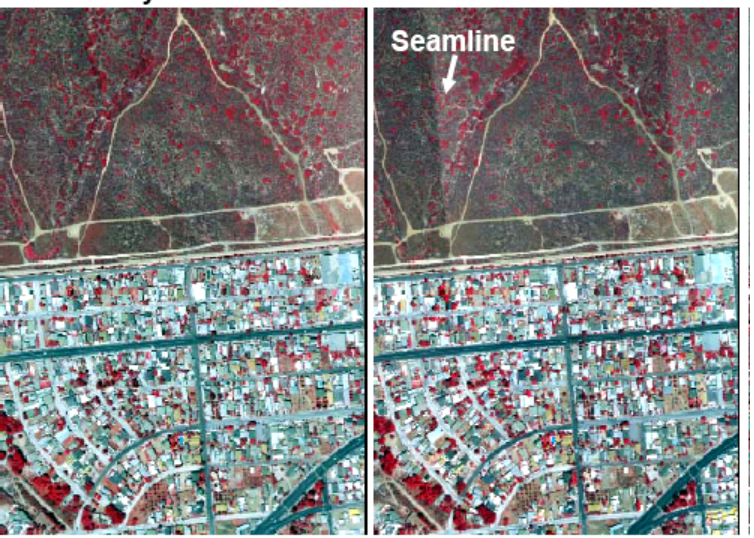
Radiometric Normalization: Window-based

May 19 2006

June 19 2006



CIR Image

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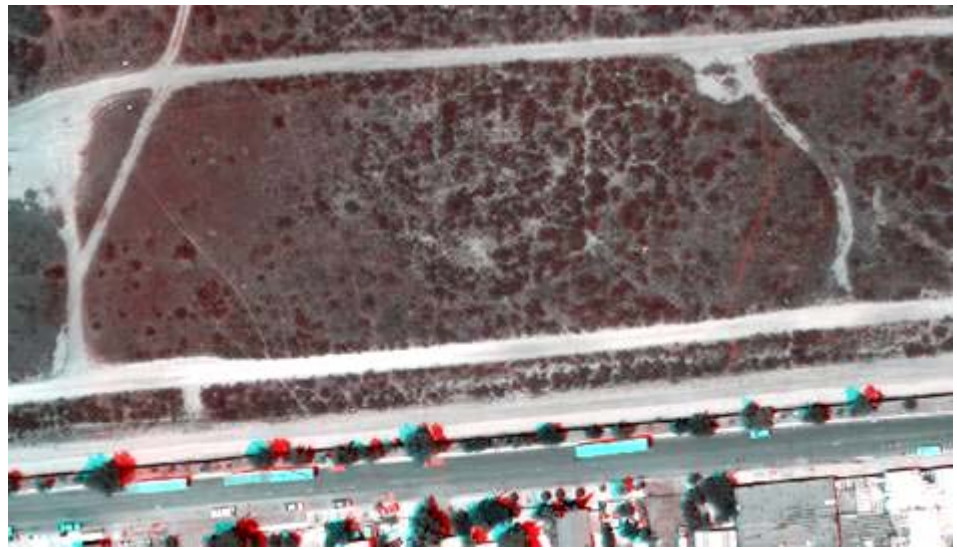
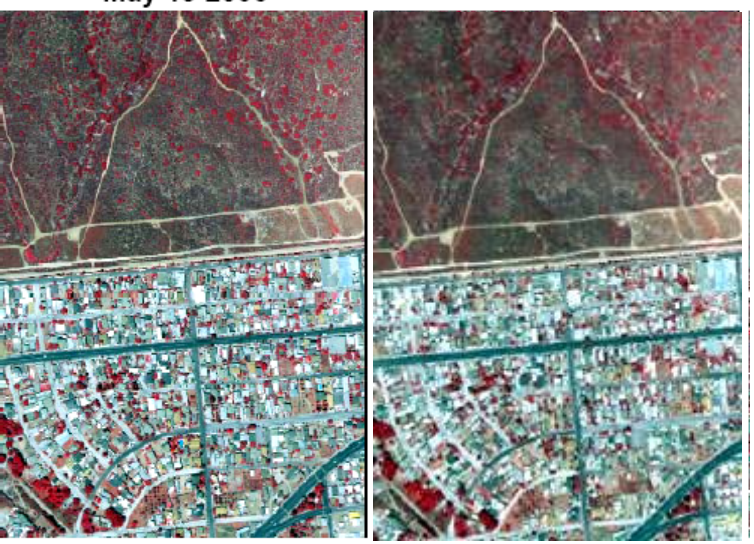


Change Composite

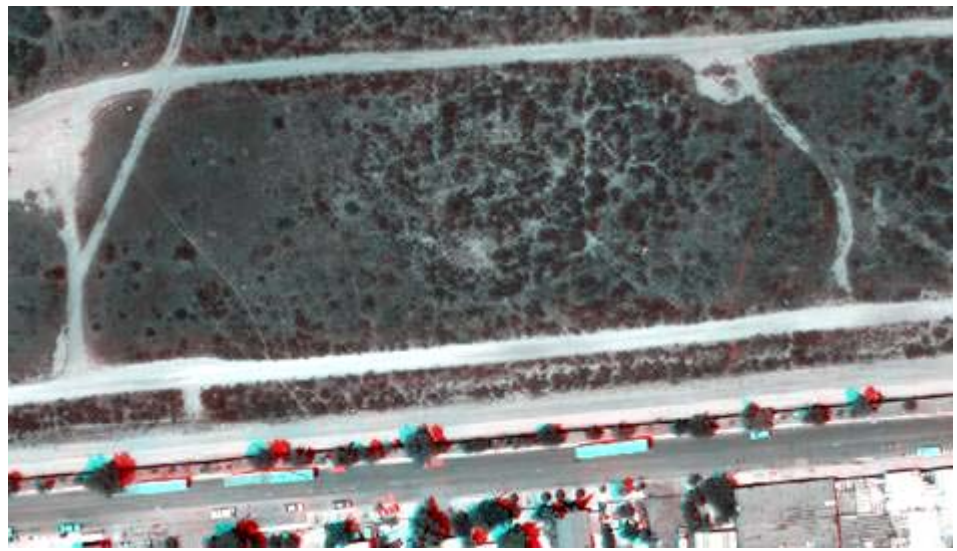
May 19 2006

June 19 2006



CIR Image

CIR Image
Corrected



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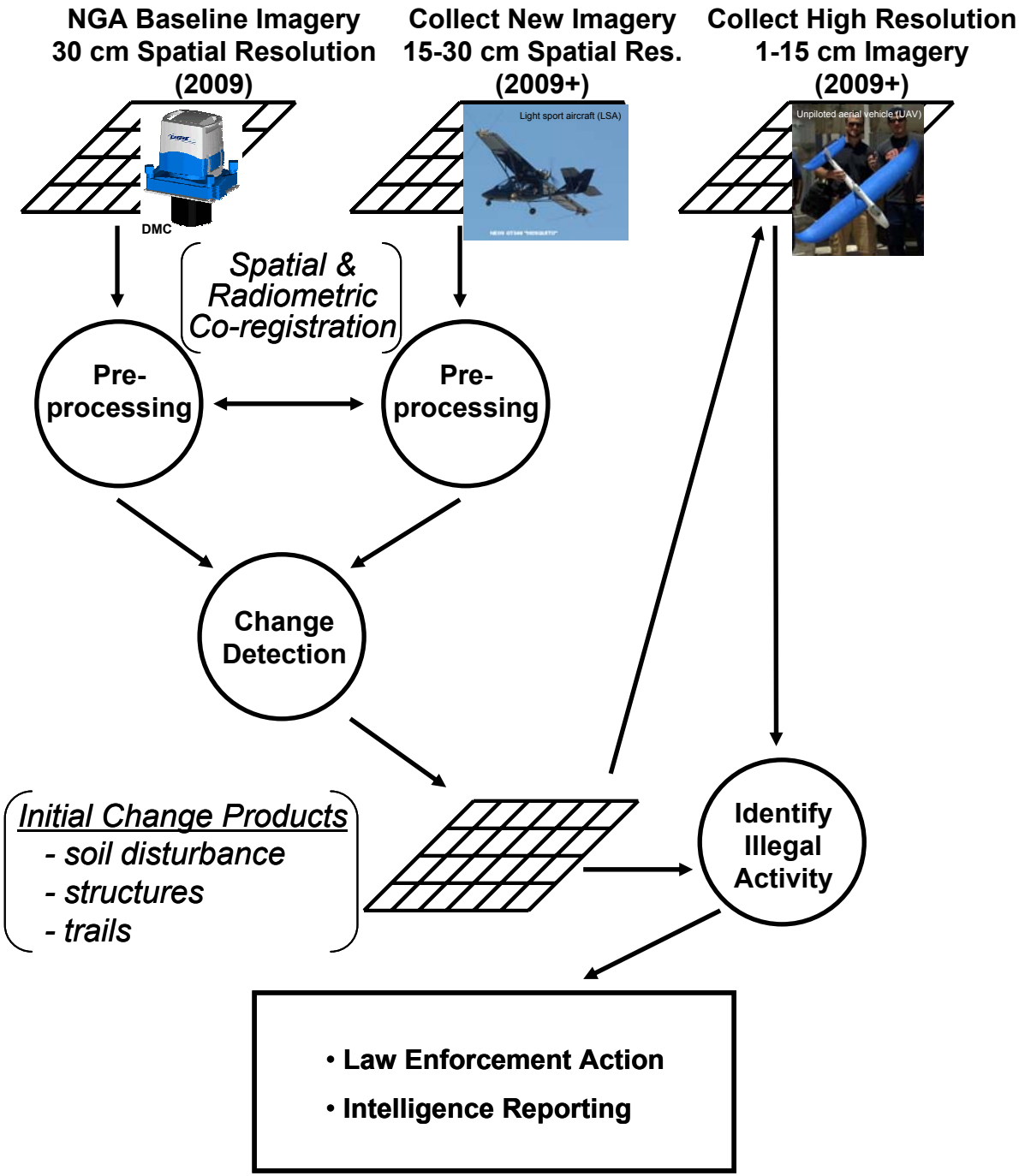
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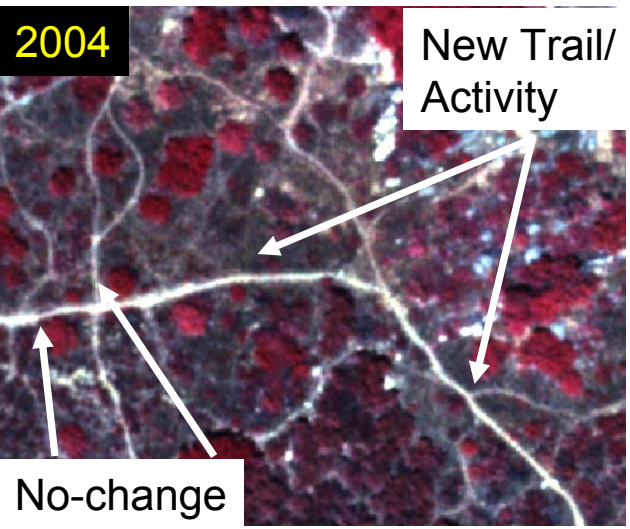
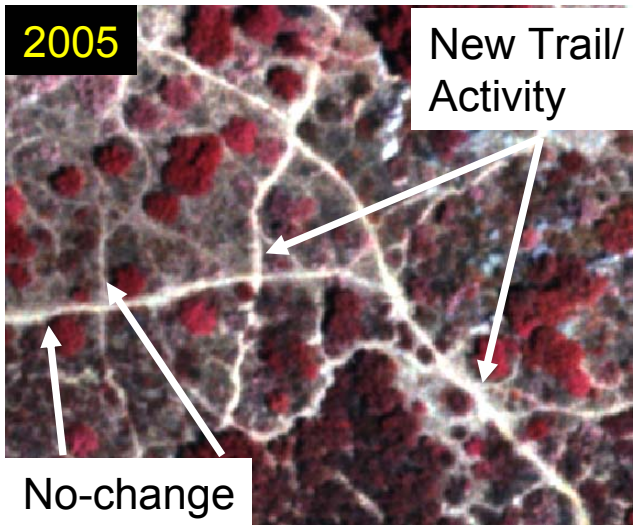
Detectable Land Cover Changes – Tecate, CA, USA

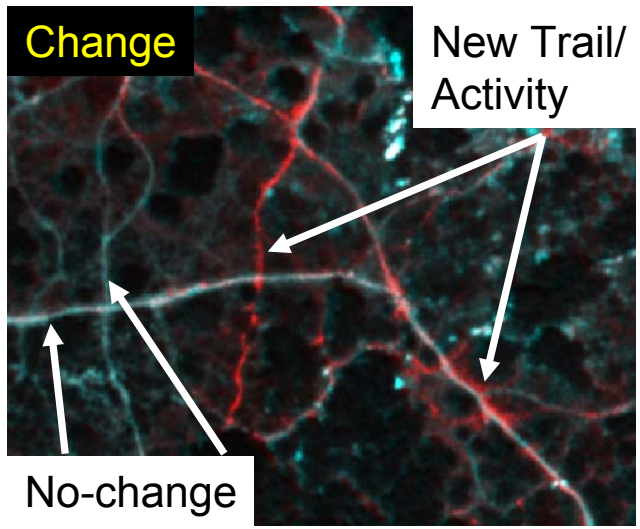
Land-based Smuggling

Trails, lay-up sites, dirt roads

- new
- increased use
- decreased use
- no change







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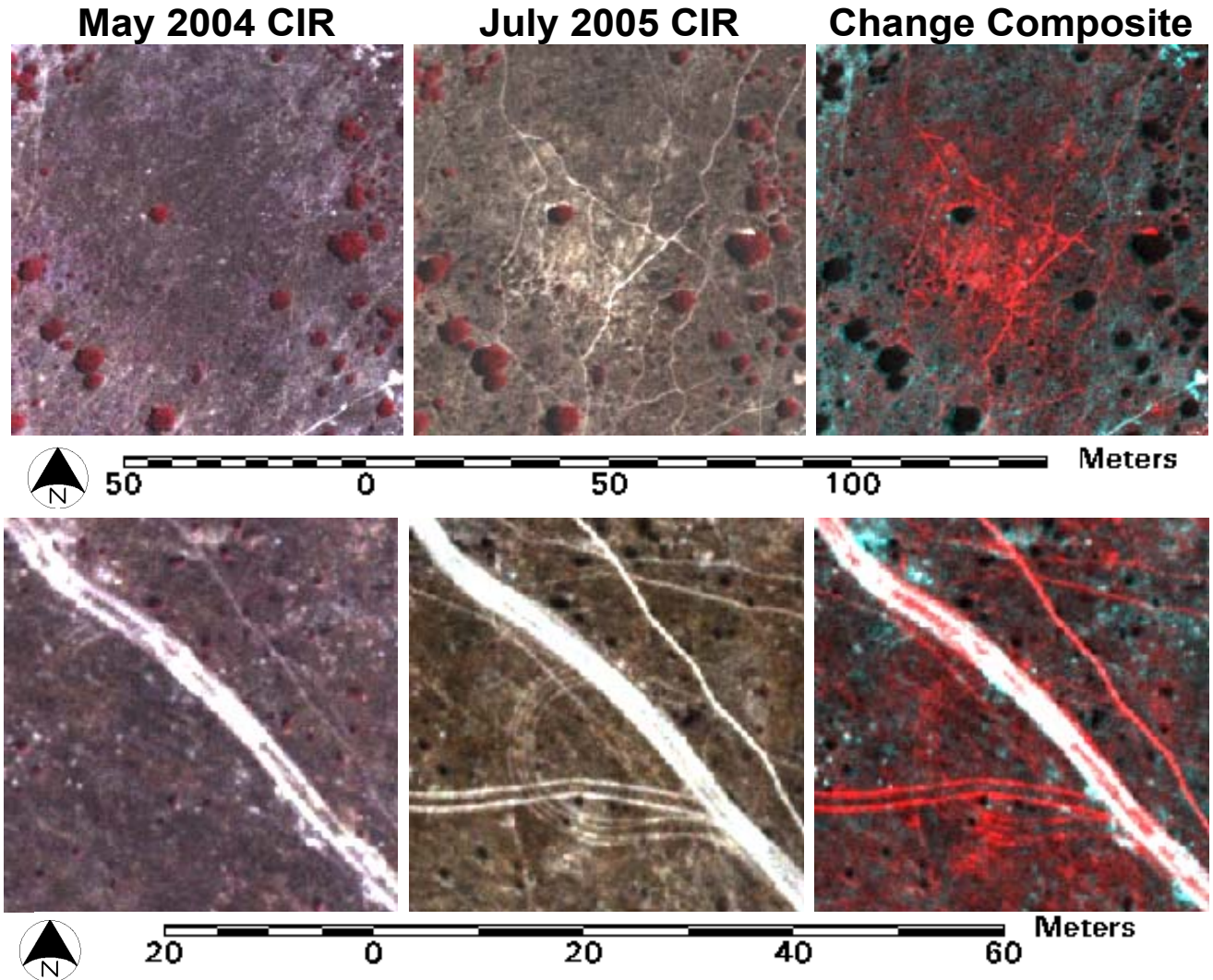

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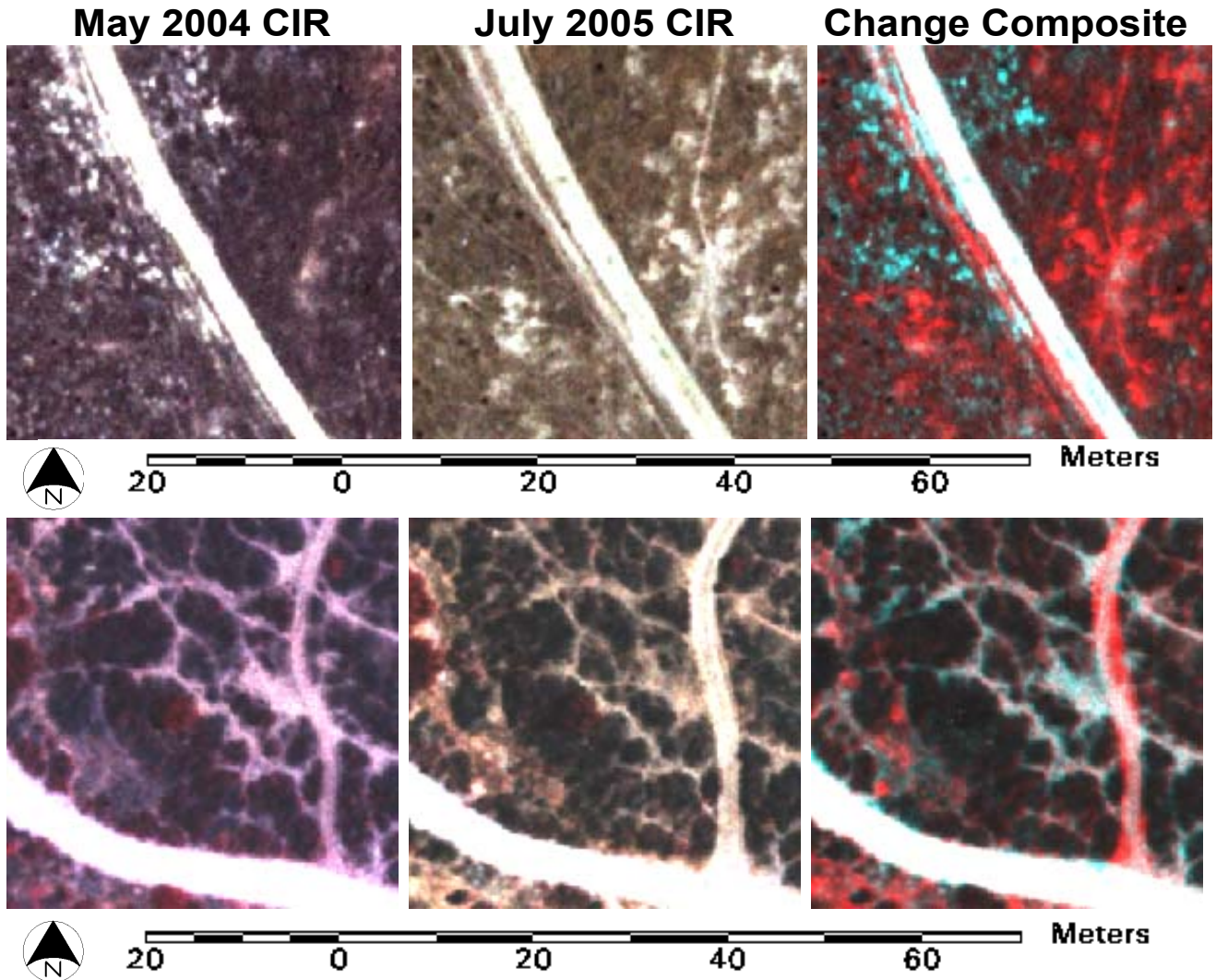


Imagery Collection – Tecate - October 27, 2008

NEOS GT500 “Mosquito”

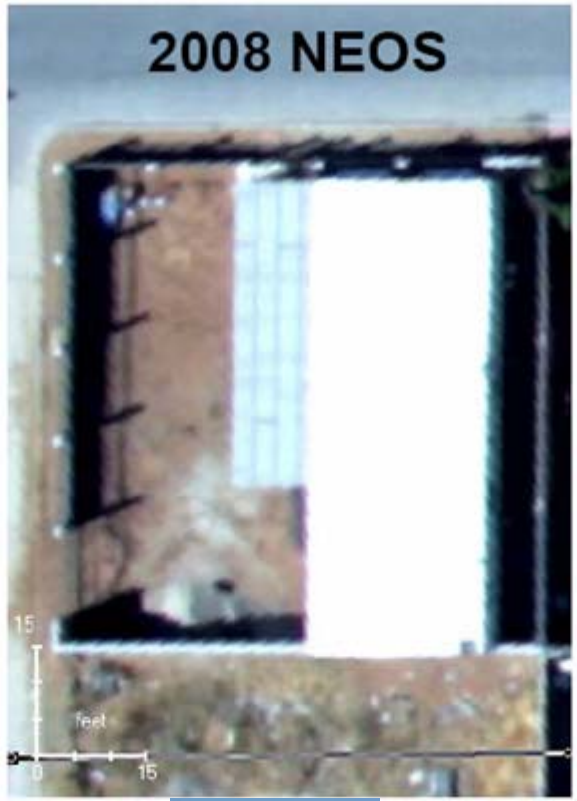
LOUIS UAV

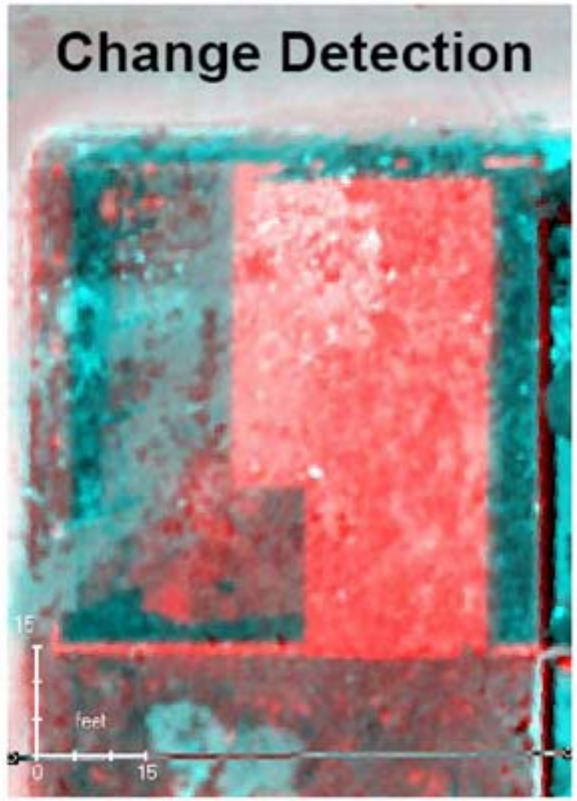
Detectable Land Cover Changes – Tecate, Mexico

Tunnel-based Smuggling

Buildings, Spoil Piles

- new
- modified





Detectable Land Cover Changes – Tecate, Mexico

Tunnel-based Smuggling

Buildings, Spoil Piles
- new
- modified

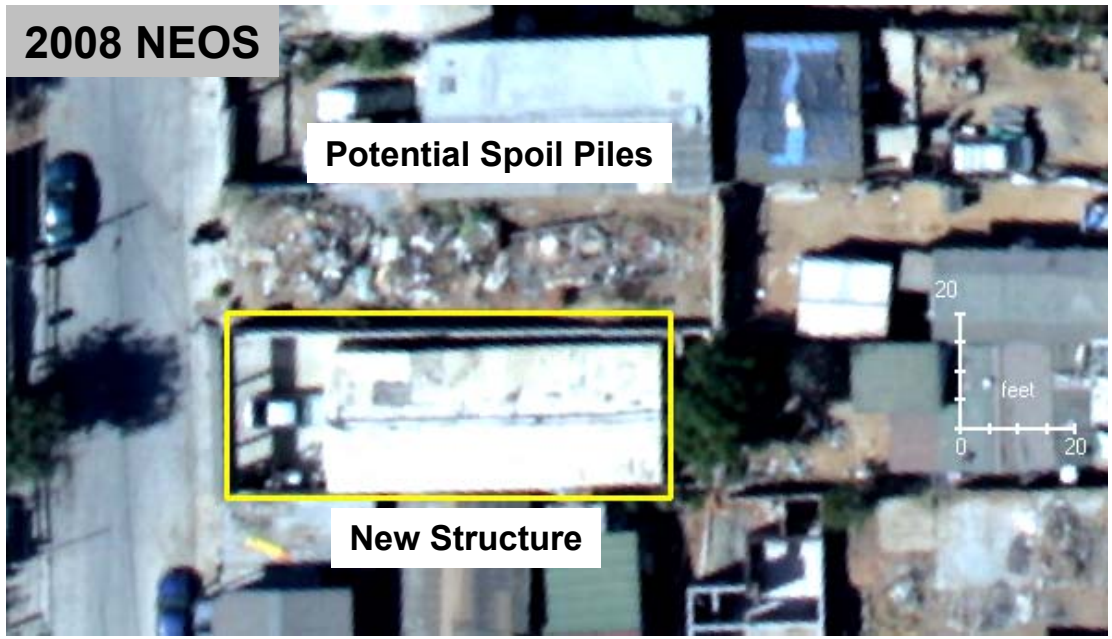
100 m from Border Fence

Detectable Land Cover Changes – Tecate, Mexico

Tunnel-based Smuggling

Buildings, Spoil Piles
- new
- modified

45 m from Border Fence



Detectable Land Cover Changes – Tecate, Mexico

Tunnel-based Smuggling

Buildings, Spoil Piles
- new
- modified

20 m from Border Fence

Detectable Land Cover Changes – Tecate, Mexico

Tunnel-based Smuggling

Buildings, Spoil Piles

- new
- modified

150 m from Border Fence

Detectable Land Cover Changes – Tecate, Mexico

Tunnel-based Smuggling

Buildings, Spoil Piles
- new
- modified

110 m from Border Fence

Detectable Land Cover Changes – Tecate, Mexico

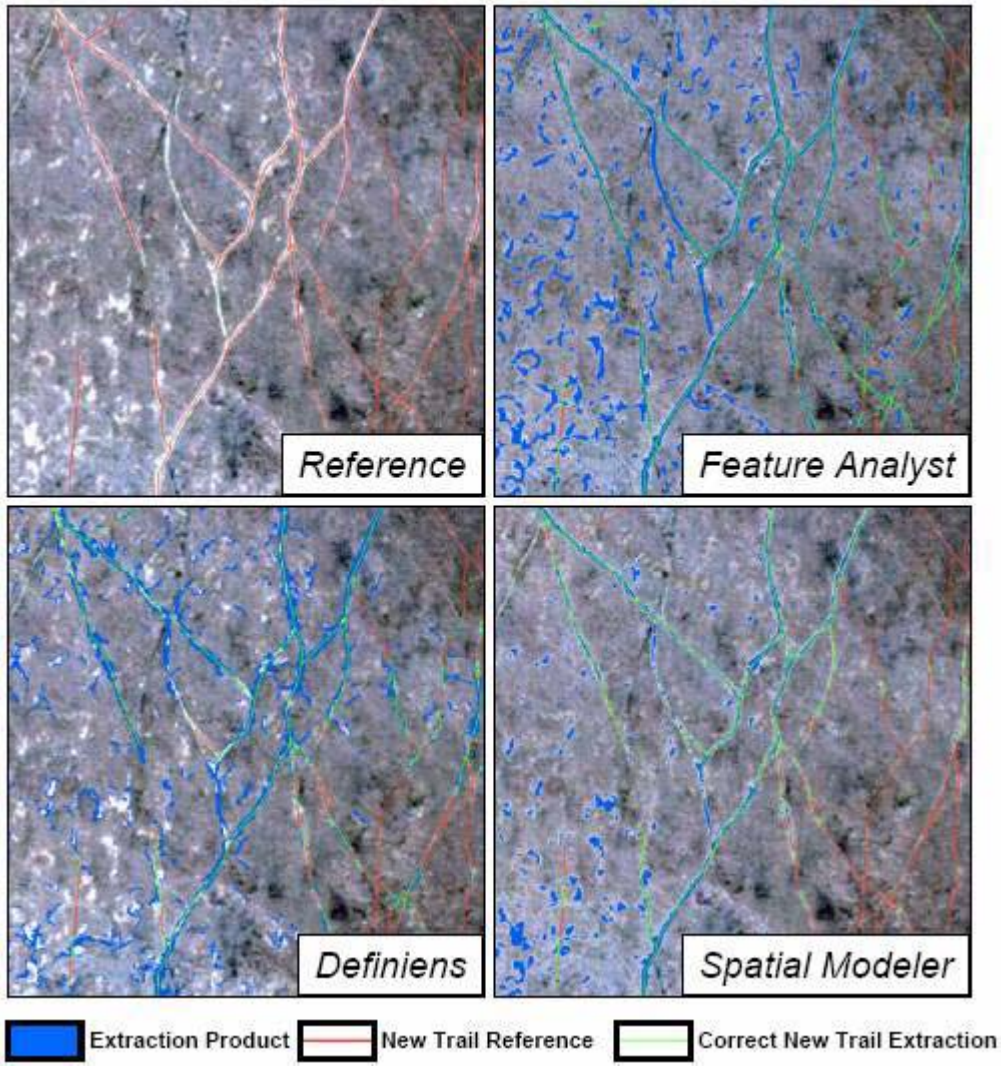
Tunnel-based Smuggling

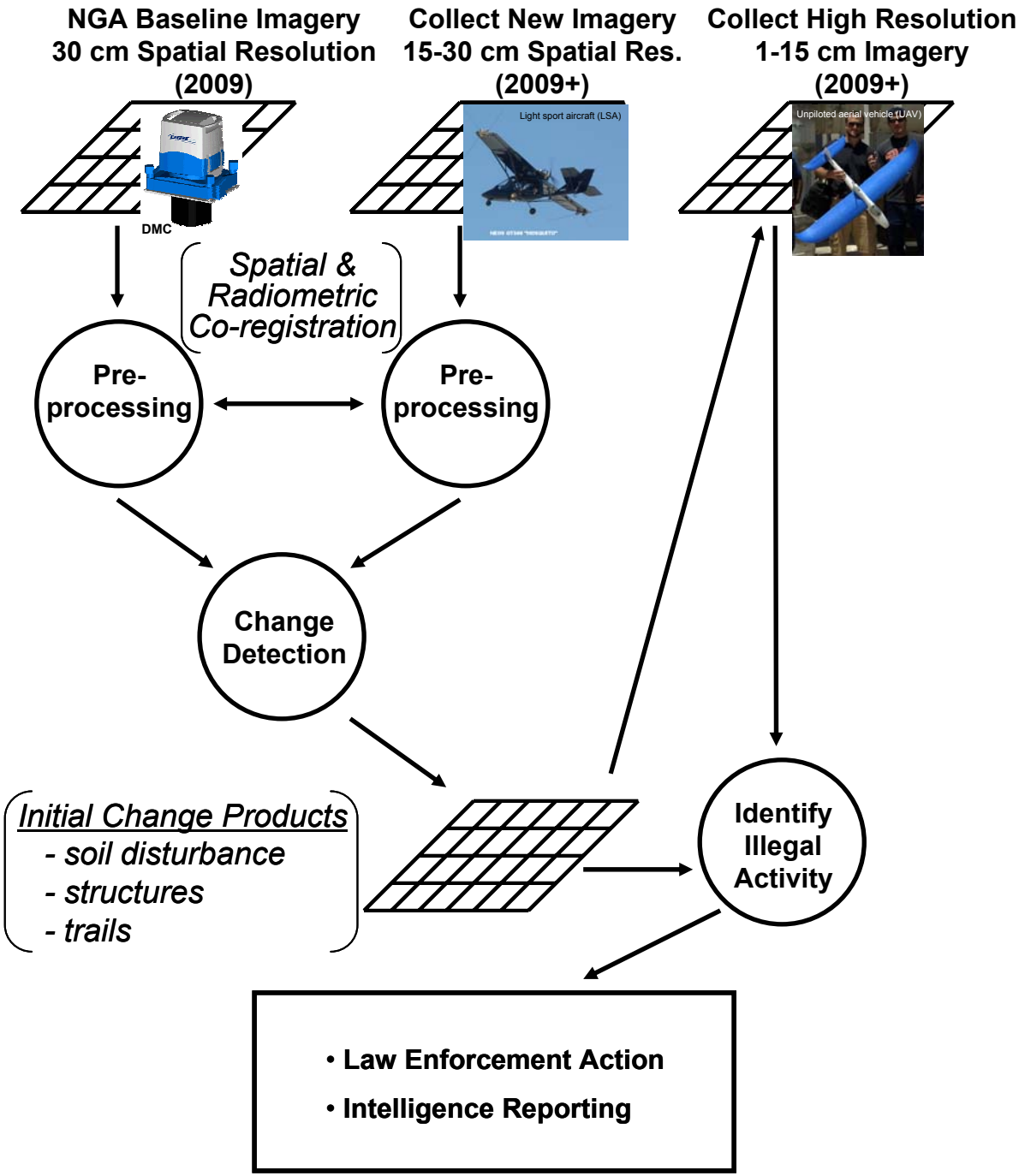
Buildings, Spoil Piles
- new
- modified

15 m from Border Fence

Semi-automated Change Detection – New Buildings

Semi-automated Change Detection – New Trails

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Reconnaissance – Ultra High Resolution Imagery

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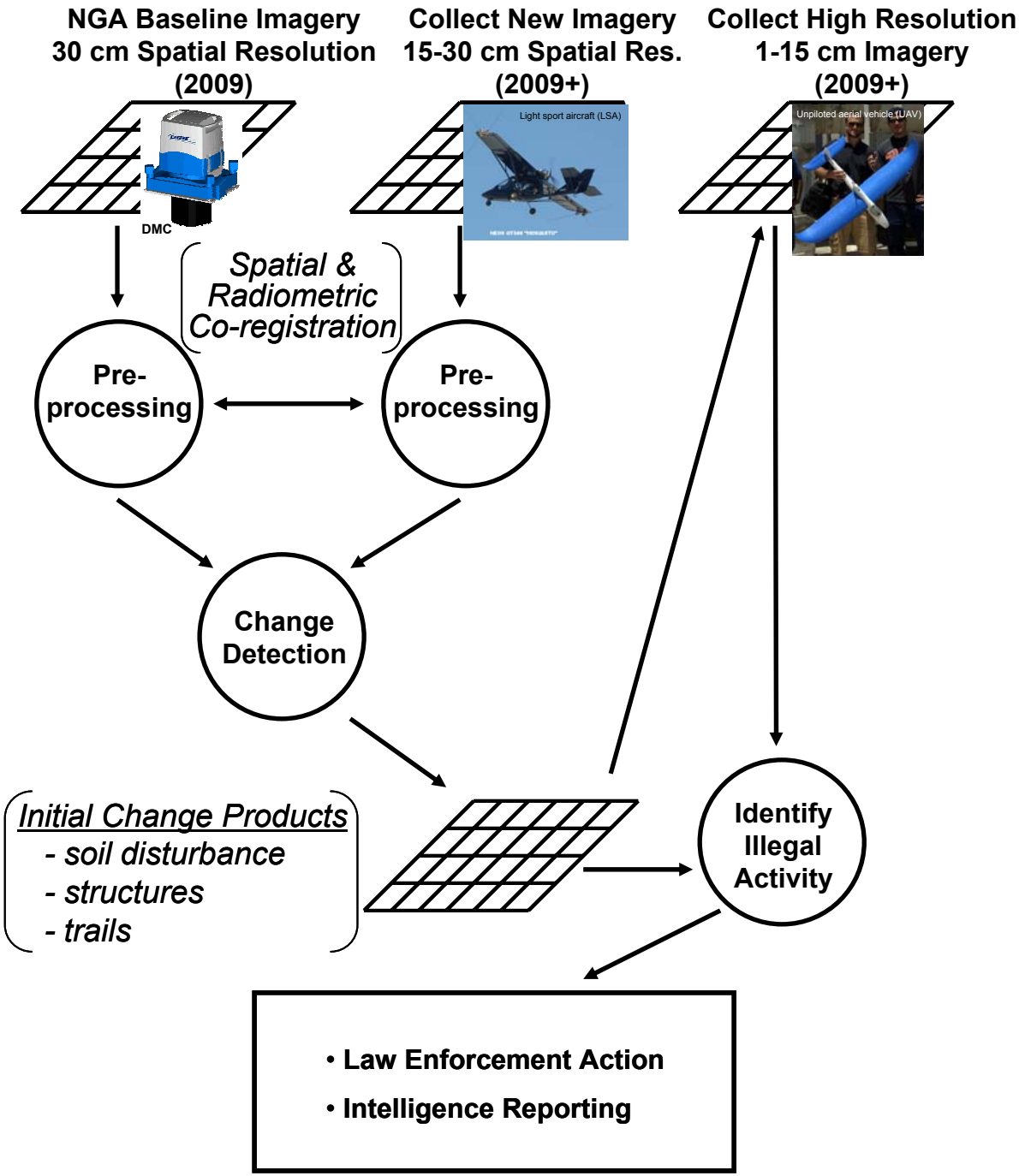
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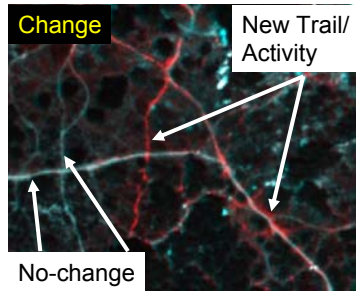
Conclusions



- Monitoring is required to detect:
  - high traffic smuggling routes
  - shifting patterns of smuggling/immigration
  - tunneling activity

- NGA border image set provides an excellent baseline data set for image-based change detection

- Low-cost solutions are available
- Automated preprecessing techniques enable detailed change detection
  - manual
    - visual review
    - multitemporal color composite
  - semi-automated
    - Feature Analyst
    - Definiens
    - Custom raster processing

Questions?